SALVATO, M. H. In press. Butterfly conservation and hostplant fluctuations: the relationship between Strymon acis bartrami and Anaea troglodyta floridalis on Croton linearis in Florida. Holarctic Lepid. 8:53-57.

SCHWARTZ, A. 1987. The butterflies of the Lower Florida Keys. Milwaukee Public Museum Contributions in Biology and Geology. No. 73. 34 pp.

SCHWARZ, K. A., R. A. WORTH & T. C. EMMEL. 1996. Conservation of two threatened south Florida butterflies and their host plant (Lepidoptera: Lycaenidae, Nymphalidae). Holarctic Lepid. 3:59-61.

SLOCUM, M. C., W. J. PLATT & H. C. COOLEY. 2003. Effects of differences in prescribed fire regimes on patchiness and intensity of fires in subtropical savannas of Everglades National Park, Florida. Restoration Ecol. 11:91-102.

SMITH, D. S., L. D. MILLER & J. Y. MILLER. 1994. The Butterflies of the West Indies and South Florida. Oxford University Press, New York. 264 pp. 32 pl.

WORTH, R. A., K. A. SCHWARZ & T. C. EMMEL. 1996. Notes on the biology of Strymon acis bartrami and Anaea troglodyta floridalis in south Florida. Holarctic Lepid. 3:62-65.

MARK H. SALVATO, *1765 17th Ave SW, Vero Beach, FL 32962 anaea_99@yahoo.com*, AND MICHAEL K. HENNESSEY, *United States Department of Agriculture, APHIS, PPQ, Center for Plant Health Science and Technology Raleigh NC 27606-5202 mike.k.hennessey@aphis.usda.gov.*

Received for publication 12 October 2003, revised and accepted 2 March 2004

Journal of the Lepidopterists' Society
58(4), 2004, 227-229

FEEDING ADULT BUTTERFLIES IN SMALL CAGES

Additional Key Words. butterfly feeder, lab-rearing, small cages

Most free-ranging butterflies feed frequently throughout their daily flight period and deteriorate if deprived of nutrients (Boggs 1997a, b, Boggs & Ross 1993). Although most caged Lepidoptera feed freely from open containers of sugar-water, they must be kept out of the solution or their wings stick together, stick to the cage, or stick to a cage mate. There is no way to clean the wings of soiled individuals and they deteriorate rapidly. Hand-held, pipette feeding is not a good long-term solution because it is time consuming and handling damages the wings, reduces longevity, and can alter behavioral and physiological phenomena being studied.

Most apparatus for feeding caged butterflies have large, exposed sticky surfaces, e.g., 1) saturated pads of polyurethane foam in 100cm petri dishes, 2) saturated cotton in 100ml beakers and 3) petri dishes of sugar water covered with bridal veil fabric (Hughes et al. 1993). Sticky surfaces are better tolerated in large cages, but cause big problems in small cages. Small cages keep the butterflies closer to the feeding station and their movements appear more erratic, less purposeful and result in frequent contact with objects in the cage. Unfortunately, large cages are not compatible with the parameters of some investigations, e.g., keeping experimental groups separated in temperature and light-control chambers, maintaining individual identification, and transporting alpine species to the lab in coolers.

Hughes et al. (1993) describe a feeder made from a conical centrifuge tube with a screw cap. The feeder I use (Fig. 1a) is similar, but is made from a syringe. Syringes are easier to fill, inexpensive, and available in more sizes. Also, the syringe barrel has flanges to hold it in place when dropped through a hole in the top of a cage. The port designed to accept a needle is plugged by forcing a round wooden toothpick into the hole and breaking or cutting it off. A single feeding port is drilled in the side of syringe, at the needle end (see Fig. 1a). A hole should not be drilled through both sides of the syringe because if one hole is drilled

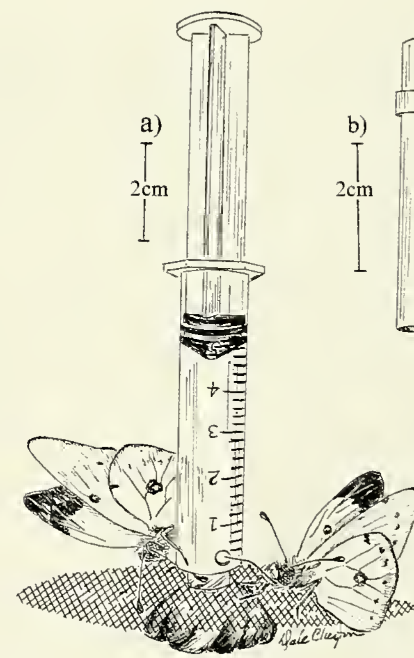

FIG. 1. a) *Colias eurytheme* at a 5 ml syringe feeder. A circle of fiberglass window screen between the syringe and modeling clay base keeps butterflies out of any sticky solution that might leak on to the cage bottom. b) A 6 X 50 mm disposable culture tube feeder with a ring cut from rubber or tygon tubing to keep it from slipping through a hole in top of the cage.

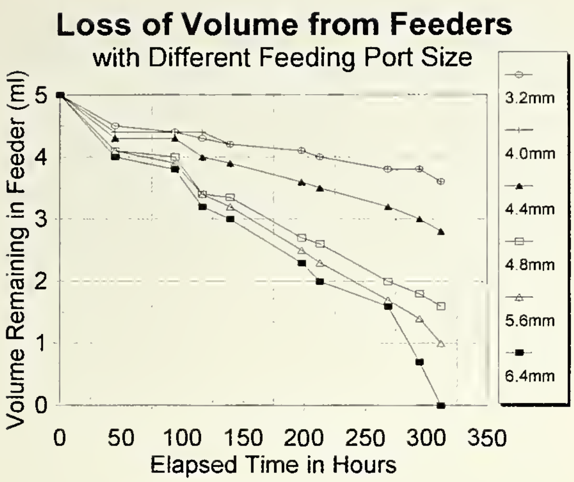

FIG. 2. Water-loss from six 10 ml syringe feeders with feeding port size ranging from 0.32 to 0.64 cm (1/8 to 1/4 inches). Each feeder held 5 ml of water and 5 ml of air at the beginning of the recording.

slightly above the other, or the syringe is tilted, air bubbles can enter the more elevated hole and fluid drains from the lower hole to the bottom of the cage. Butterflies have no problem finding a single small hole. Yellow or red food coloring in the fluid, and/or colored tape near the feeding-port can serve as orientation cues. Common food flavorings (eg., anis, mint, vanilla) can be added as attractants.

This feeder can be suspended through a hole in the top of the cage or held upright by inserting the needle port into a piece of modeling clay or into a hole drilled in a small block of wood. A circular piece of fiberglass screen held just above the cage floor by the modeling clay base (see Fig. 1a) will keep the subjects out of sticky fluids that may drip from the feeder.

To determine the best hole size, I made six 10 ml feeders with holes graded from 3.2 to 6.4 mm (1/8 to 1/4 inch) in diameter. The butterflies I tested (e.g. *Asterocampa celtis*, *Oeneis chryxus*, *Erebia epipsodea*, *Danaus plexippus*) found the small holes as readily as the large holes. I filled the syringes to the 5 ml mark with water and the remaining 5 ml, with air to test the effect of changes in air volume with temperature and barometric pressure. No dripping was detected, but all feeders lost water due to evaporation, and the one with the largest hole (6.4 mm) went dry on day 13. A plot of volume change (Fig. 2) shows that the feeders lost water proportionally to the cross-sectional area of the holes drilled into them. Water loss was approximately 0.0005 ml/mm^2/hr for all hole sizes. Fig. 2 suggests that environmental changes (eg., humidity, air currents) caused similar shifts in the rate of water loss from all pore sizes, over time. These shifts are more evident for larger diameter ports. If feeding rates are being tested, a control feeder can be used to correct data for such incidental fluid loss.

The volume scale on the syringe is convenient for quantifying ad-lib feeding rates or preferences between different nutrients, colors, flavors, etc. Plastic syringes can be obtained in a variety of sizes from a pharmacy or veterinary supply. Small diameter syringes (0.5 and 1.0 ml) give more precise measurement of small volume consumption.

A second type of feeder I use in small cages is a 6 X 50 mm disposable culture tube (Fig. 1b). These tubes are inexpensive and common in microbiology labs, or they can be made by heat sealing one end of glass tubing. These feeders are best filled using a syringe and needle to deliver fluid to the bottom of the tube. After filling, the tube can be inverted and slipped through a hole in the top of the cage. A 3-5 mm long ring of tygon or rubber tubing, fitted near the closed end of the tube (see Fig. 1b), keeps it from slipping through the hole. The tube diameter is small enough that fluid will not drip, but air bubbles form and rise to keep fluid at the lower end.

Reference to "sugar-water" was used to simplify discussion and not to imply that it is an adequate diet for adult Lepidoptera. Hill (1989) and Boggs (1997a, b) demonstrated that amino acids and other nutrients obtained by both adults and larva affect fecundity and longevity in some species. Among free-ranging Lepidoptera, some species depend entirely on nutrients obtained as larva and never feed as adults, e.g., female Megathyminae (Scott 1986). Others require energy from carbohydrates found in nectar (Romeis & Wackers 2000, 2002). Lepidoptera with longer, more complex adult lives have more complex nutritional needs, including electrolytes, amino acids, lipids, and carbohydrates, to repair anatomical structures, maintain physiological homeostasis, produce gametes, migrate, defend territories and other adult activities (Karlsson 1998, Schappert 2001). Butterflies feed from a variety of sources including nectar, pollen, tree sap-flows, over-ripe fruit, mud puddles (imbibing water to concentrate salts and minerals), bird and mammal excrement, blood, sweat, tears, and other body fluids (Dowes 1973, Banziger 1971, Arms et al. 1974, Scott 1986, Boggs & Jackson 1991, Erhardt & Baker 1990, Estrada & Jiggins 2002, DeVries et al.1997, Mevi-Schutz & Erhardt 2002, Penz 2000, Romeis & Wackers 2002 . Rusterholz & Erhardt 2000, Krenn et al. 2001, Schappert 2001).

LITERATURE CITED

ARMS, K., P. FEENY & R. C. LEDERHOUSE. 1974. Sodium: Stimulus for puddling behavior by tiger swallowtail butterflies, *Papilio glaucus*. Science 185:372-374.

BANZIGER, H. 1971. Bloodsucking moths of Malaya. Fauna 9:4-16.

BOGGS, C. L. 1997a. Reproductive allocation from reserves and income in butterfly species with differing adult diets. Ecology 78:181-191.

—— 1997b. Dynamics of reproductive allocation from juvenile and adult feeding: Radio tracer studies. Ecology 78:192-202.

BOGGS, C. L. & L. A. JACKSON. 1991. Mud puddling by butterflies is not a simple matter. Ecol. Entomol. 16:123-127.

BOGGS, C. L. & C. L. ROSS. 1993. The effect of adult food limitation on life history traits in *Speyeria mormonia* (Lepidoptera: Nymphalidae). Ecology 74:433-441.

DEVRIES, P. J., D. MURRAY & R. LANDE. 1997. Species diversity in vertical, horizontal, and temporal dimensions of a fruit-feeding butterfly community in an Ecuadorian rainforest. Biol. J. Linn. Soc. 62:343-364.

DOWES, J. A. 1973. Lepidoptera feeding at puddle margins, dung and carrion. J. Lep. Soc. 27:89-99.

ERHARDT, A. & I. BAKER. 1990. Pollen amino acids-an additional diet for a nectar feeding butterfly? Plant Syst. & Evol. 169:111-121.

ESTRADA, C. & C. D. JIGGINS. 2002. Patterns of pollen feeding and habitat preference among *Heliconius* species. Ecol. Entomol. 27:448-456.

HILL, C. J. 1989. The effect of the adult diet on the biology of butterflies. 2. The common crow butterfly, *Euploea core corinna*. Oecologia 81:258-266.

HUGHES, P. R., C. D. RADKE & J. A. A. RENWICK. 1993. A simple, low-input method for continuous laboratory rearing of the monarch butterfly (Lepidoptera:Danaidae) for research. Amer. Entomol. 39:109-111.

KARLSSON, B. 1998. Nuptial gifts, resource budgets, and reproductive output in a polyandrous butterfly. Ecology 79:2931-2940.

KRENN, H. W., K.P. ZULKA & T. GATSCHNEGG. 2001. Proboscis morphology and food preferences in nymphalid butterflies (Lepidoptera:Nymphalidae). Jour. Zool. 254:17-26.

MEVI-SCHUTZ, J. & A. ERHARDT. 2002. Can *Inachis io* detect nectar amino acids at low concentrations? Physiol. Entomol. 27:256-260.

PENZ, C. M. 2000. Behavioral adaptations to pollen-feeding in *Heliconius* butterflies (Nymphalidae: Heliconinnae): An experiment using Lantana flowers. J. Insect Behav. 13:865-880.

ROMEIS, J. & F. L. WACKERS. 2000. Feeding response by female *Pieris brassicae* butterflies to carbohydrates and amino acids. Physiol. Entomol. 25:247-253.

—— 2002. Nutritional suitability of individual carbohydrates and amino acids for adult *Pieris brassicae*. Physiol. Entomol. 27:148-156.

RUSTERHOLZ, H. P. & A. ERHARDT. 2000. Can nectar properties explain sex-specific flower preferences in the Adonis Blue butterfly *Lysandra bellargus*? Ecol. Entomol. 22:220-224.

SCHAPPERT, P. 2001. Butterfly buffet. Natural History 110:46-49.

SCOTT, J. A. 1986. The butterflies of North America. Stanford University Press. Stanford. 583pp.

DALE L. CLAYTON, *Department of Biology, La Sierra University, 4700 Pierce Street, Riverside, CA 92515*

Received for publication 4 November 2003, revised and accepted for publication 10 February 2004